



4GLS
DARESBUY

INDUCING STRONG DENSITY MODULATION WITH SMALL ENERGY DISPERSION IN PARTICLE BEAMS AND THE HARMONIC AMPLIFIER FREE ELECTRON LASER

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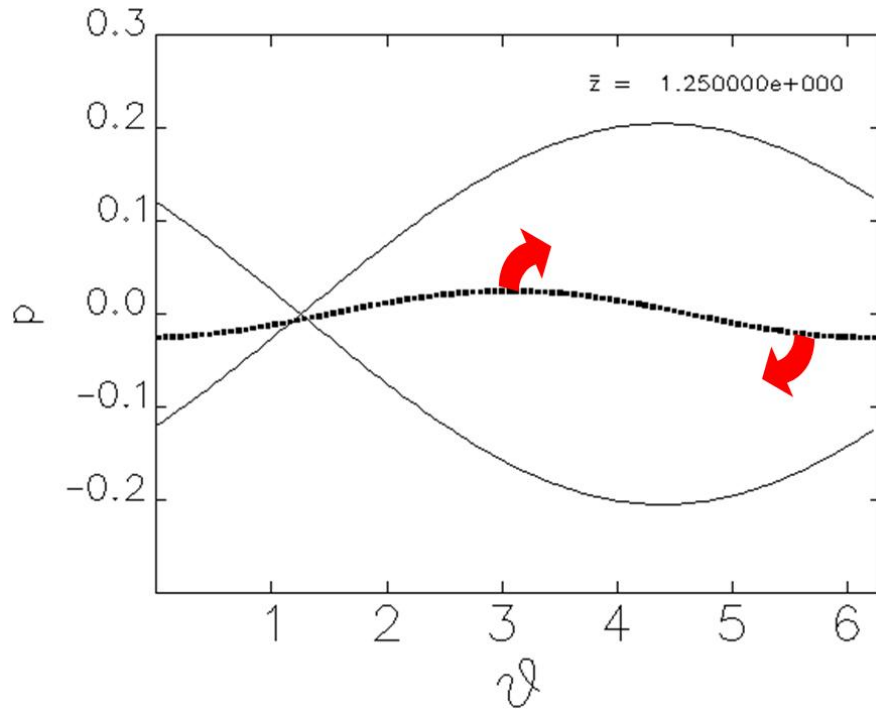
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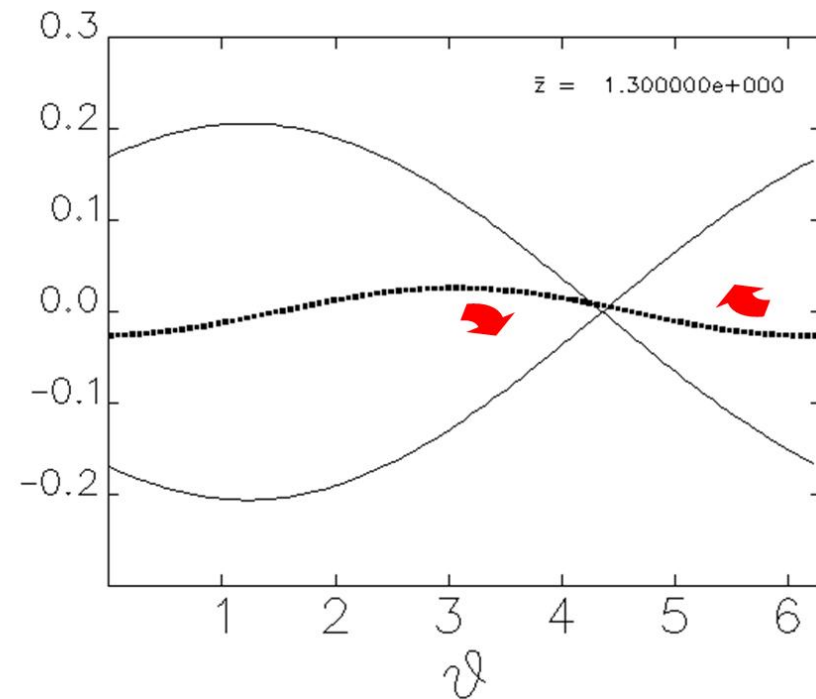


Density Modulation With Reduced Energy Dispersion

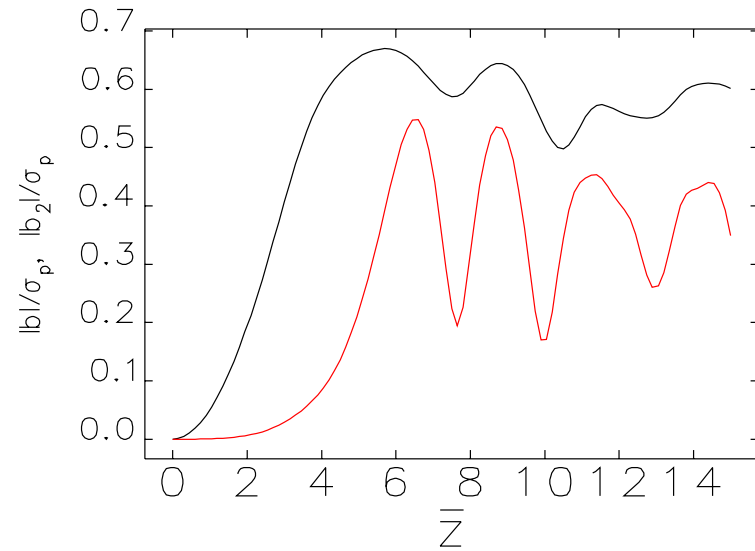
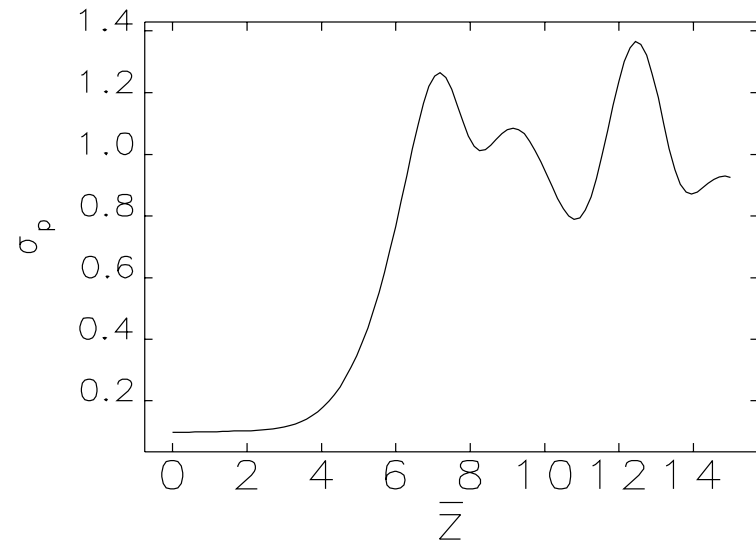
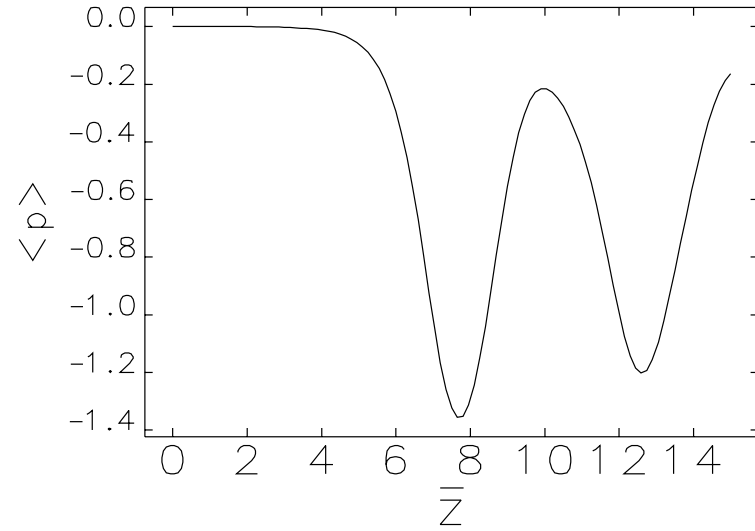
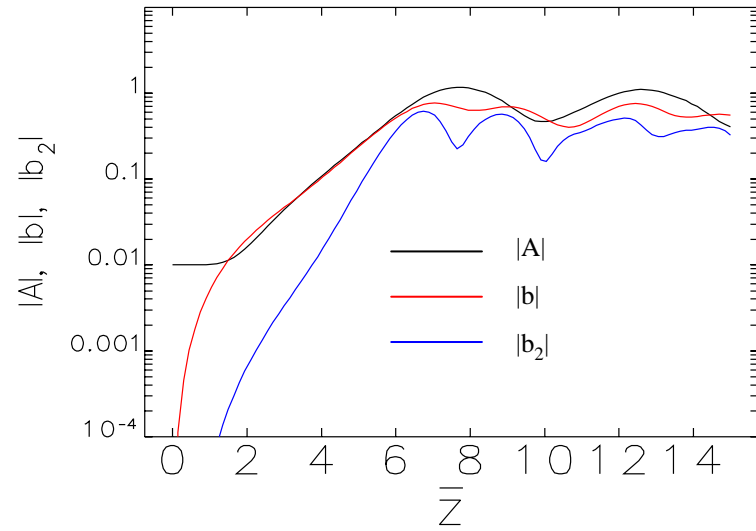


Start of normal
FEL-like instability
in phase space

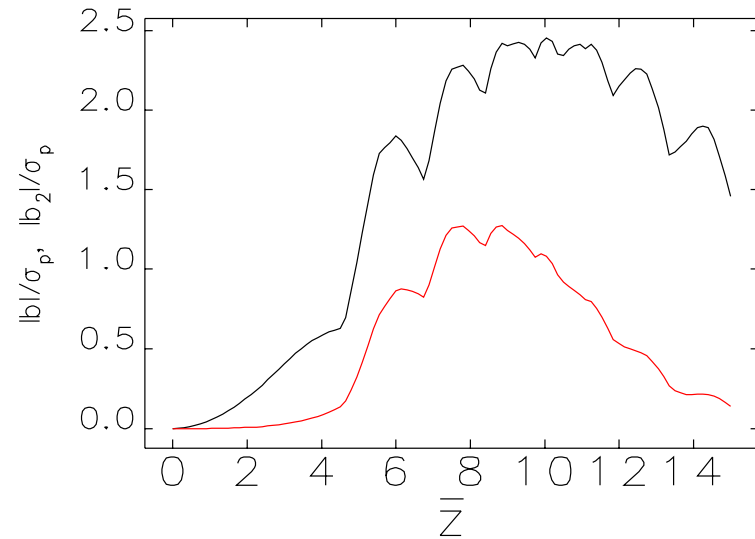
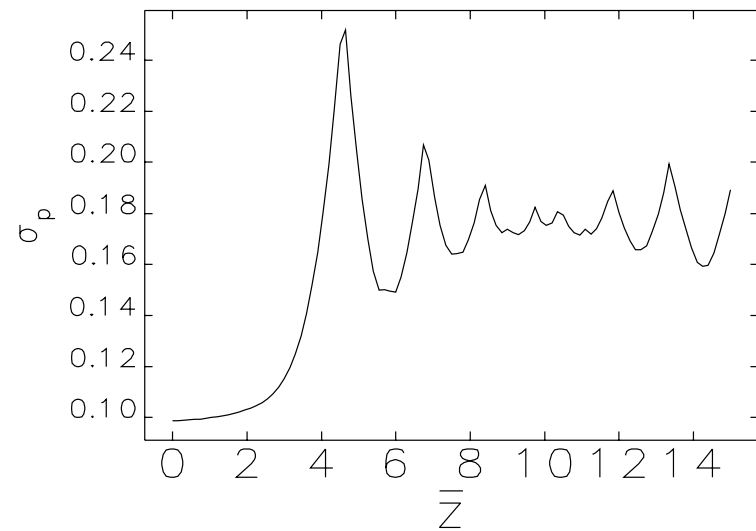
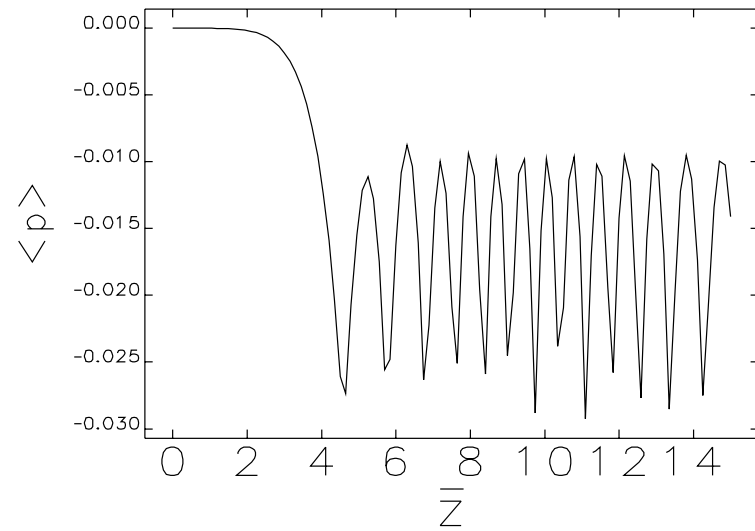
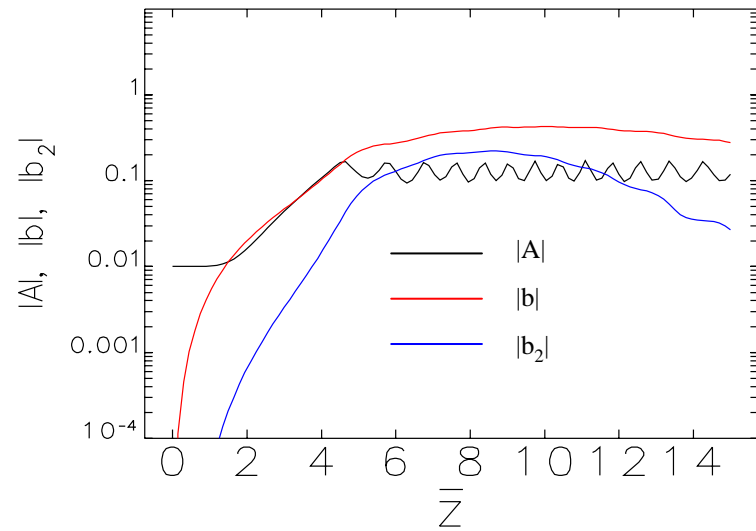
Phase space after a
relative π phase change
between electrons and
radiation field



Steady State High Gain FEL

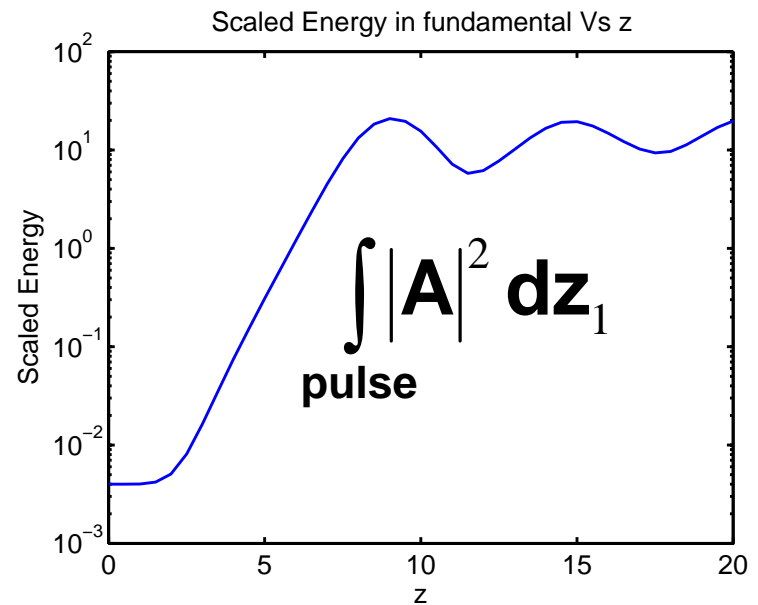
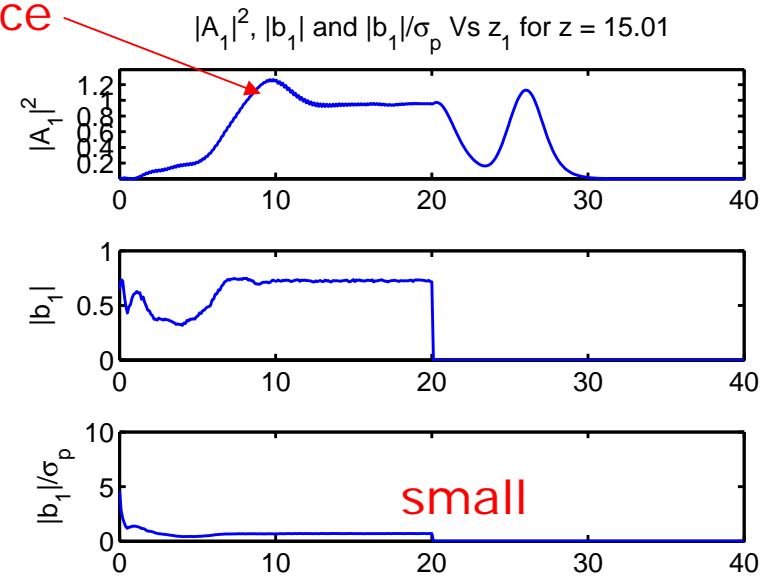
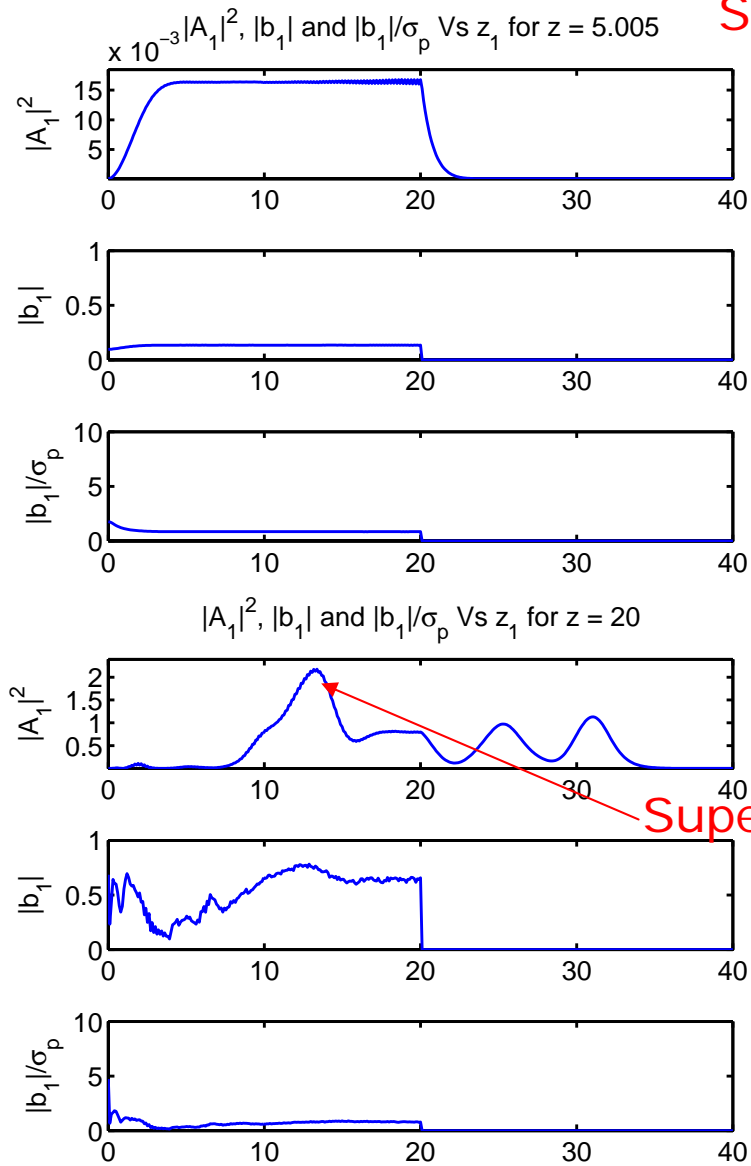


Steady State FEL with π -phase switching

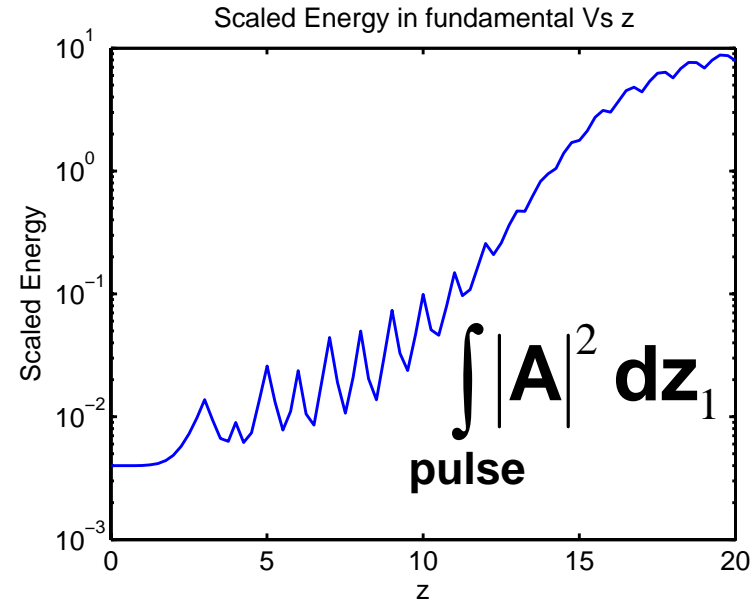
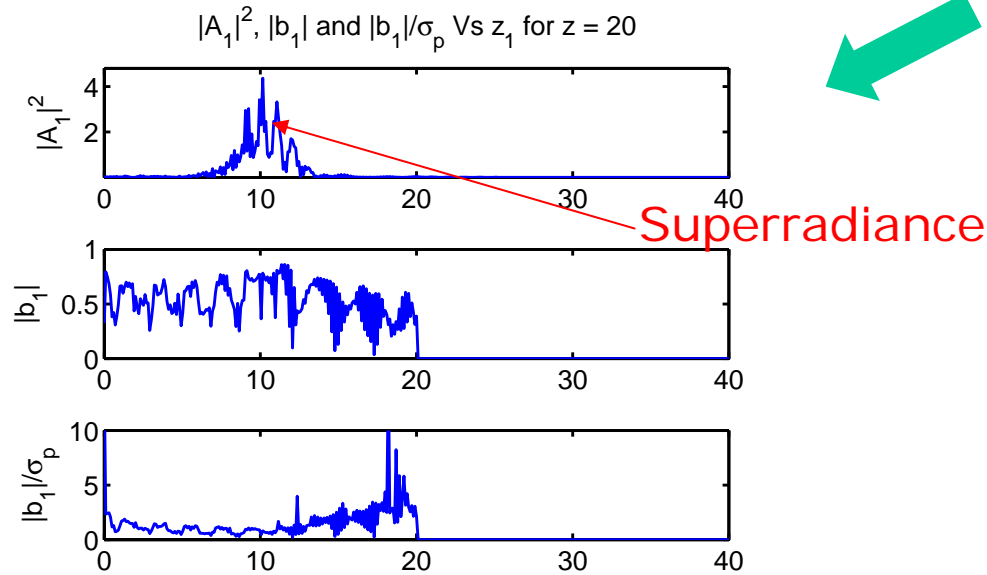
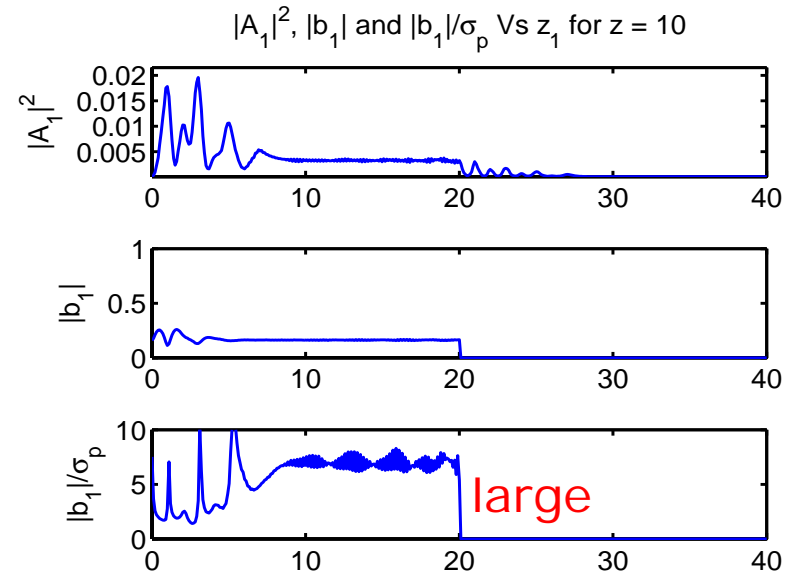
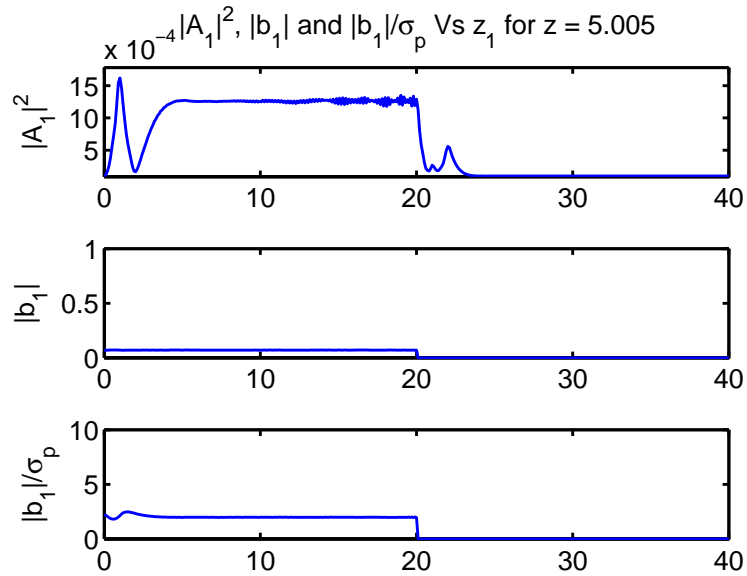


Seeded Pulsed High Gain FEL

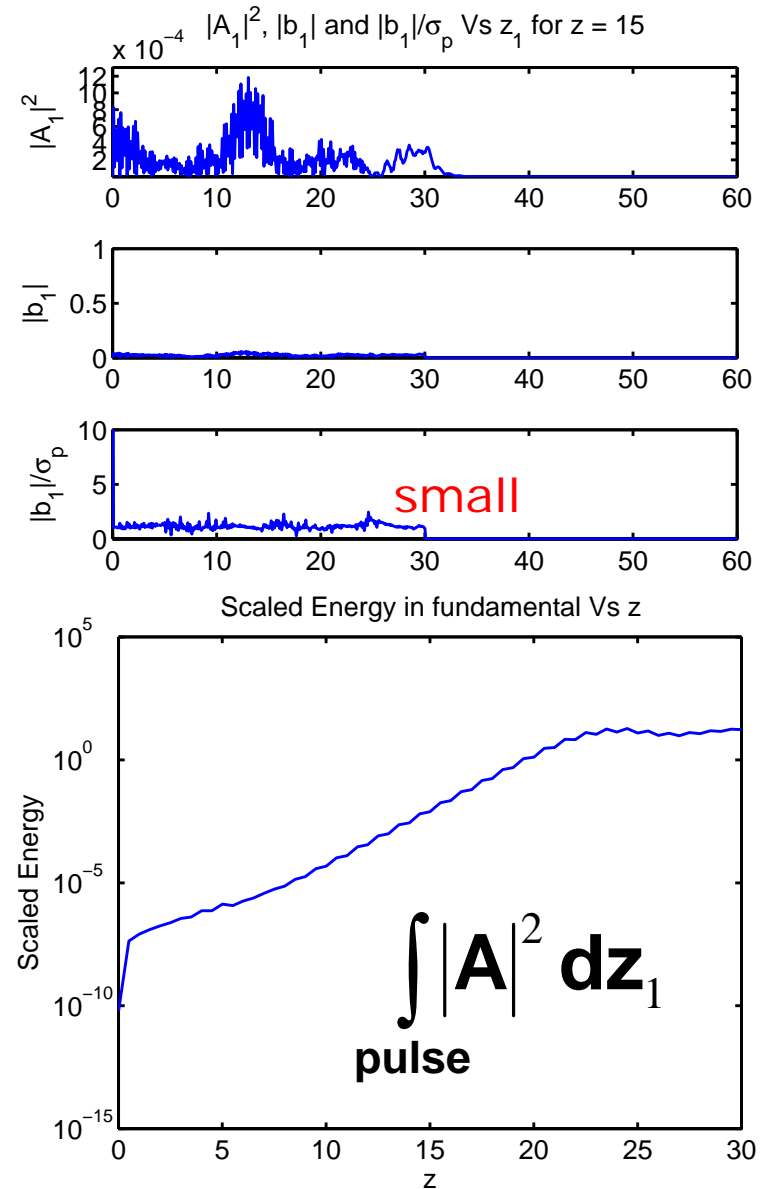
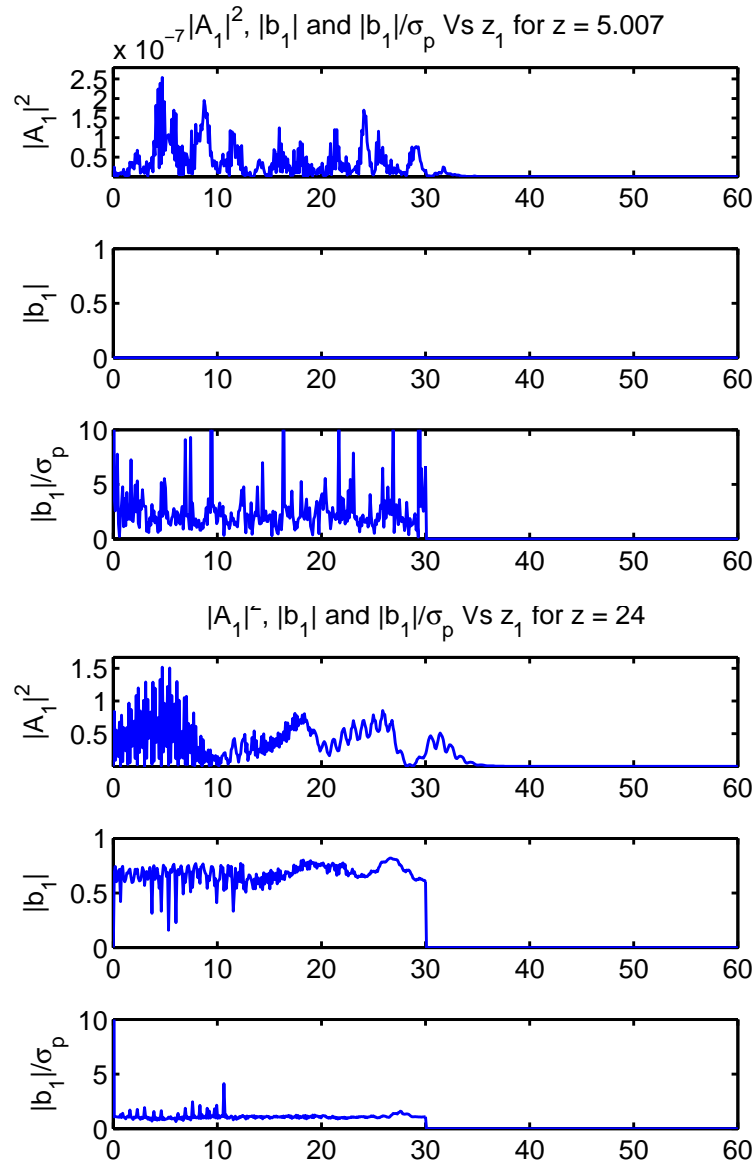
Superradiance



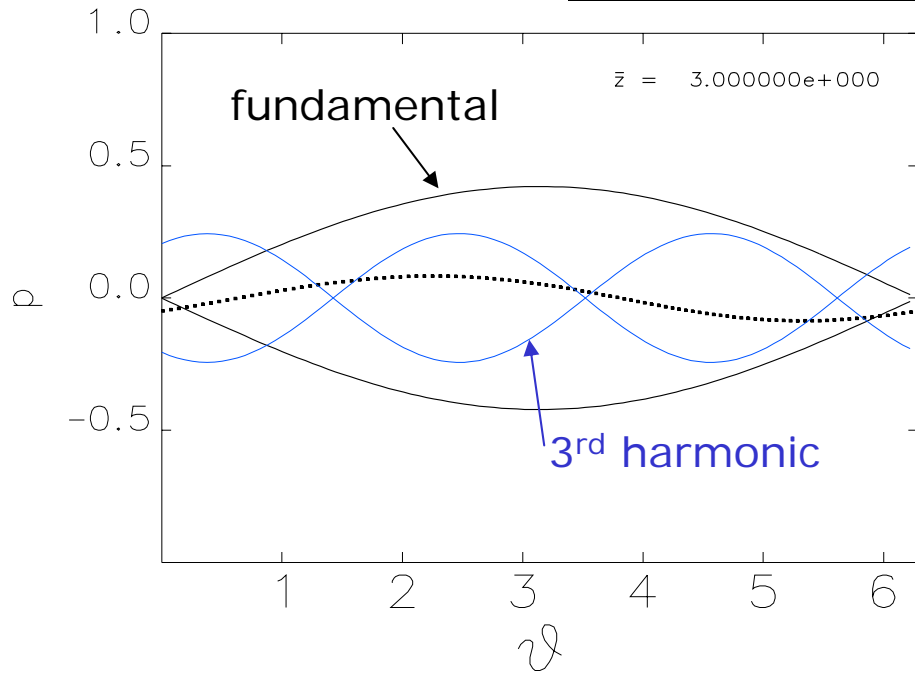
Seeded Pulsed High Gain FEL with π -phase switching



SASE Pulsed High Gain FEL with π -phase switching

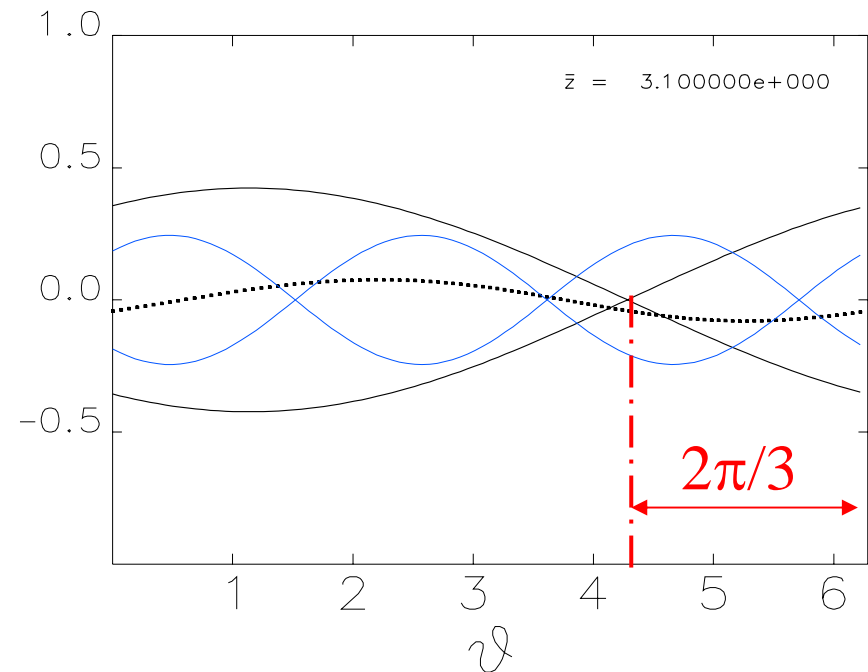


Harmonic Amplifier FEL

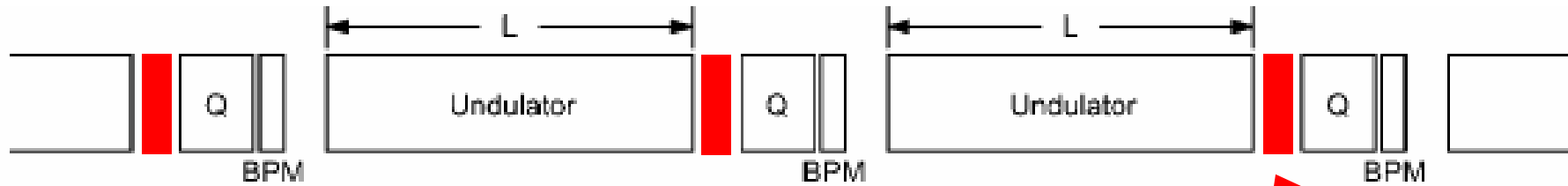


A relative phase change between electrons and fundamental radiation of $2\pi/3$ will disrupt the coupling and FEL exponential growth

However, A $2\pi/3$ phase change for the fundamental is a 2π phase change for the 3rd harmonic - it suffers no disruption and can dominate the fundamental!

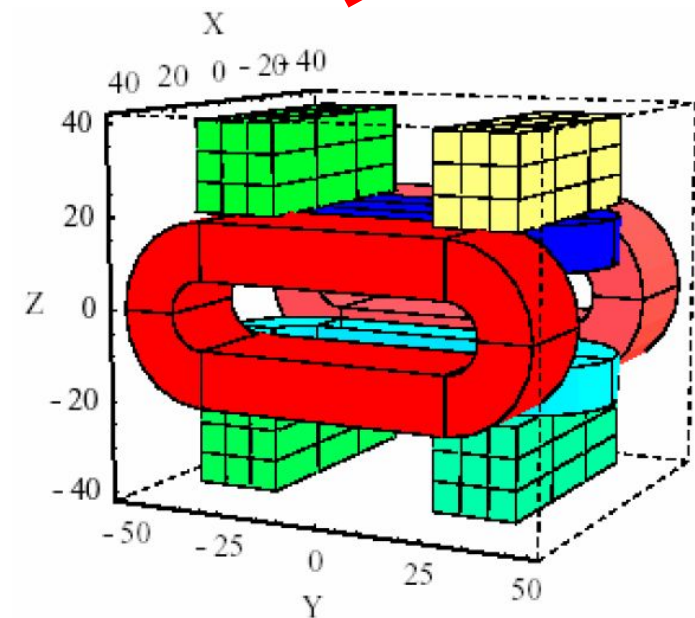


Simple to effect phase changes between undulator sections



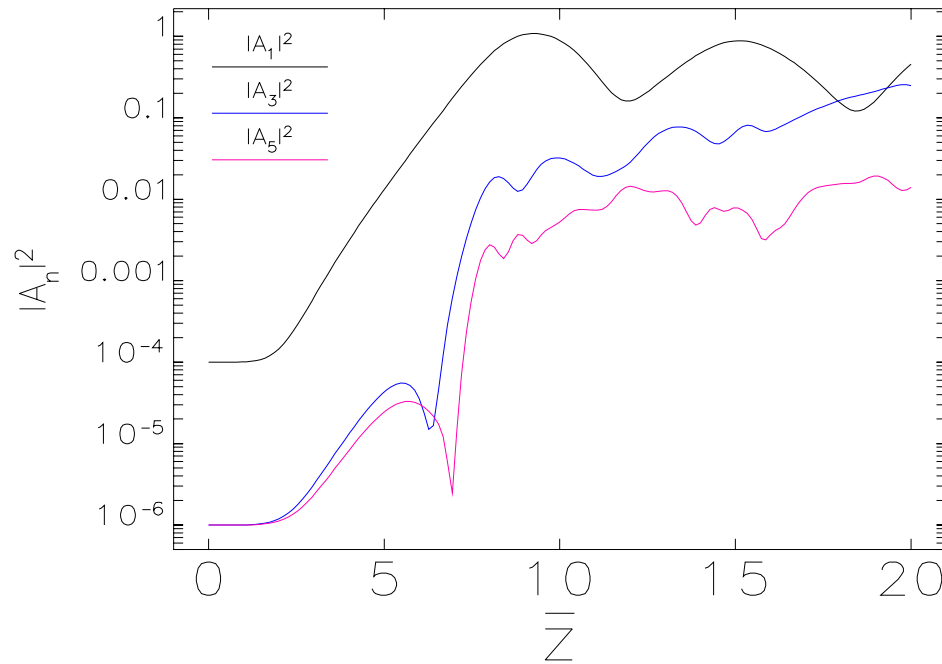
Phase shifters are easily inserted between undulator sections. They:

- Have a small footprint $\sim 10\text{cm}$
- Are fully tunable over range of phase shifts required
- Are already integral part of most FEL designs



Bessy-FEL Phase-shifter

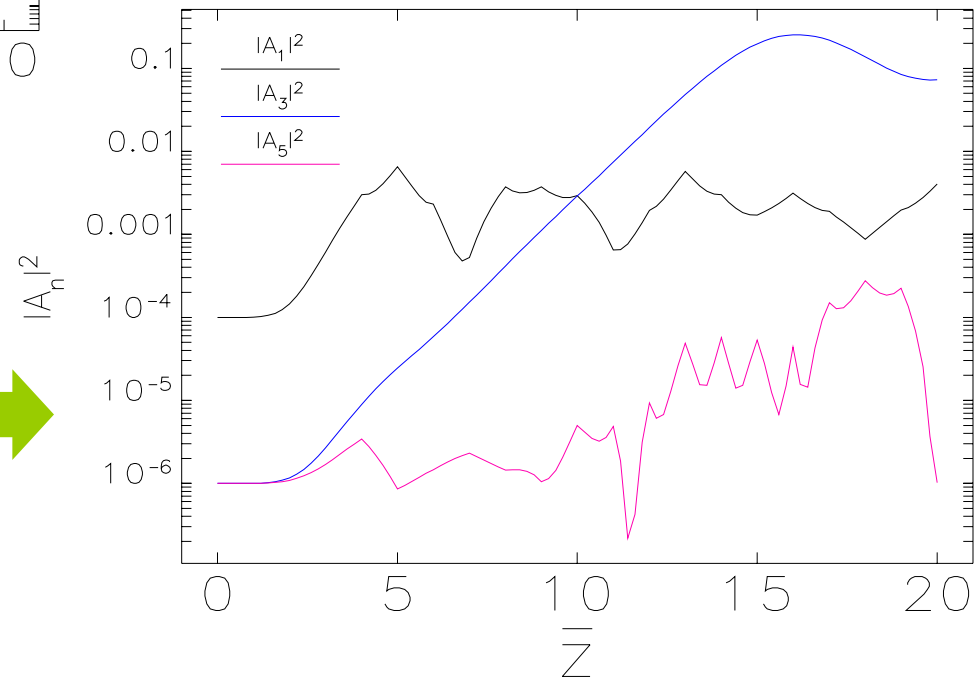
Steady-state Harmonic Amplifier FEL



Normal planar FEL amplifier including the 3rd & 5th harmonics (Undulator $a_w=3$)



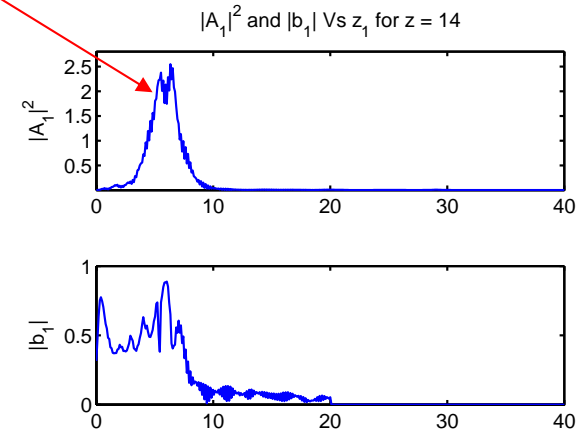
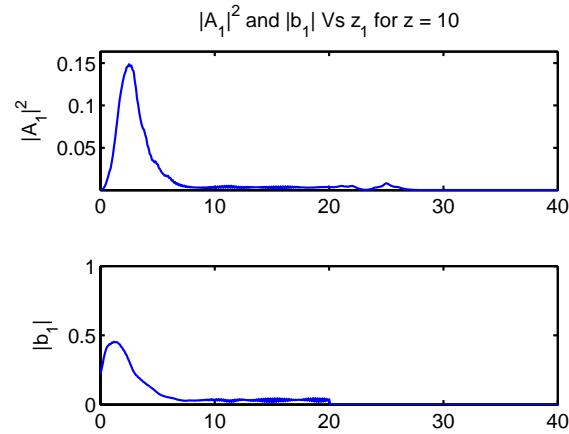
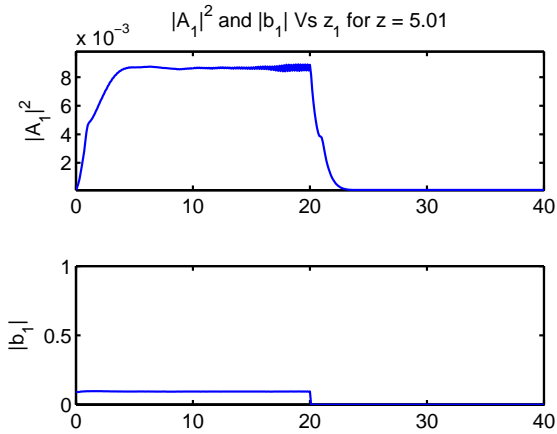
Harmonic Amplifier FEL demonstrating dominance of 3rd harmonic over fundamental & 5th harmonic



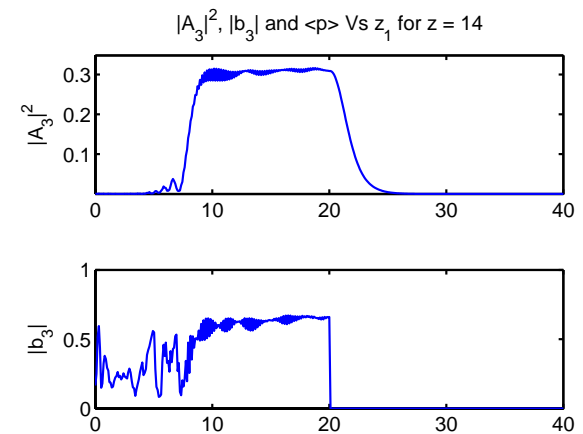
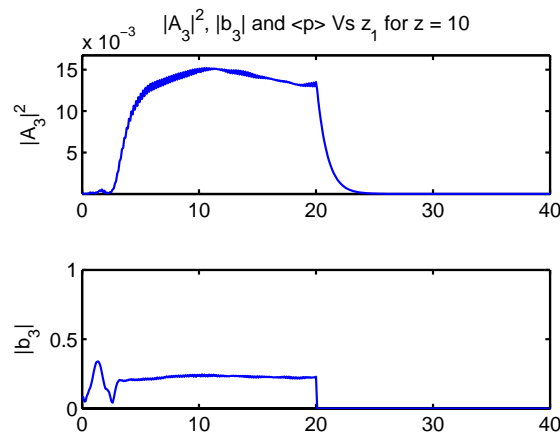
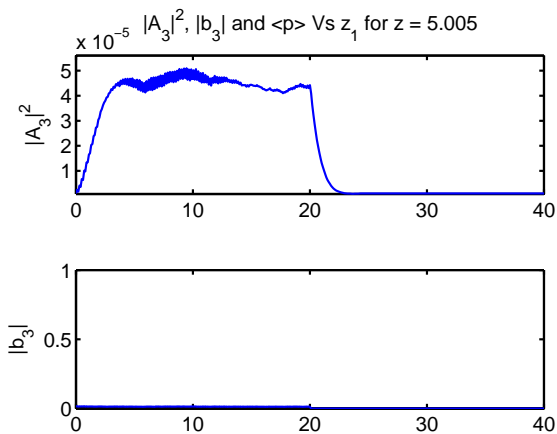
Seeded Harmonic Amplifier FEL (pulses)

Fundamental:

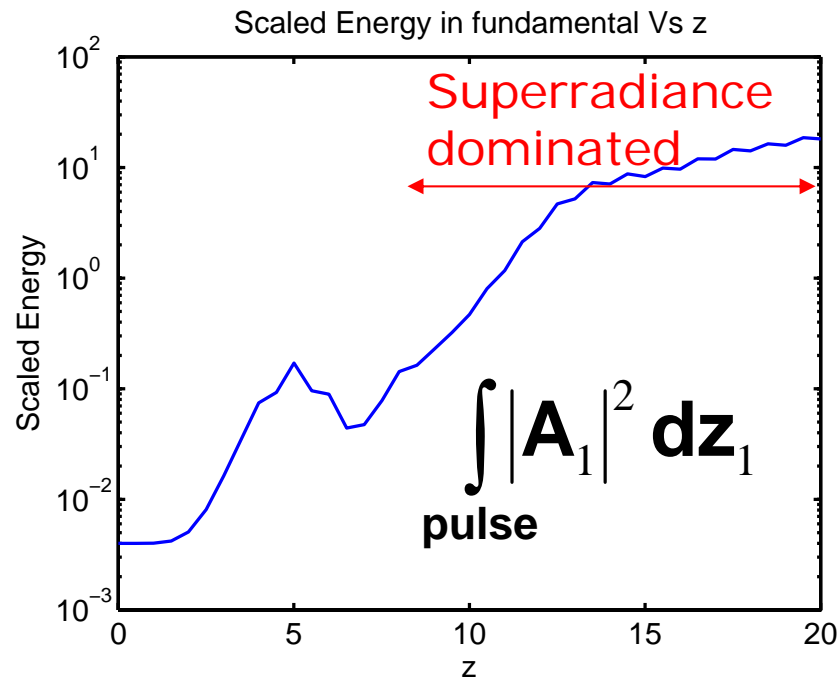
Superradiance



3rd Harmonic:

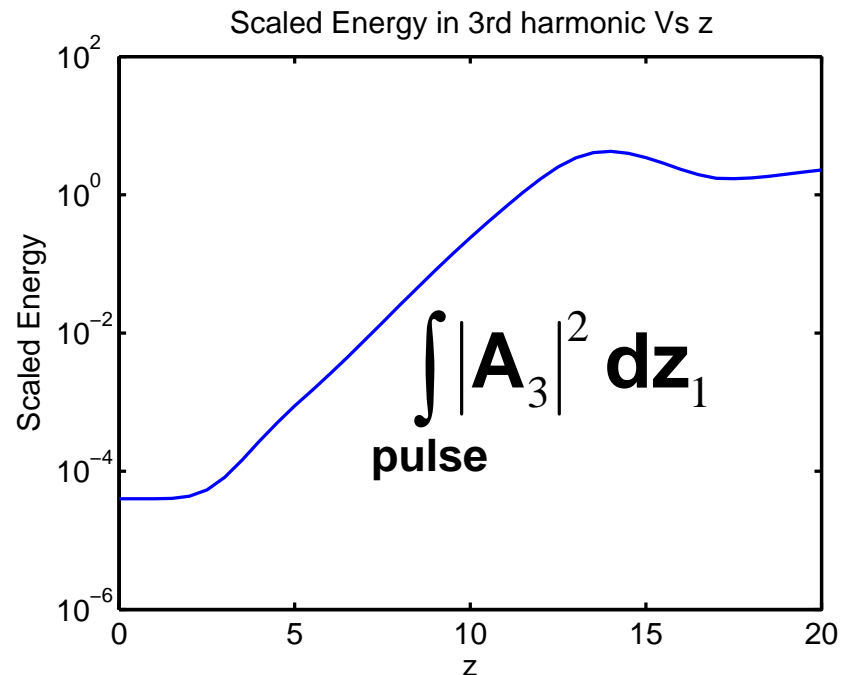


Seeded Harmonic Amplifier FEL (pulses)



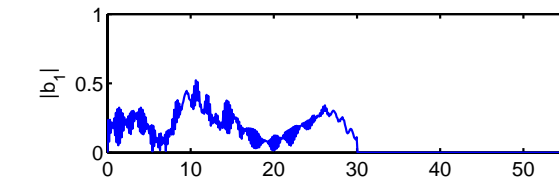
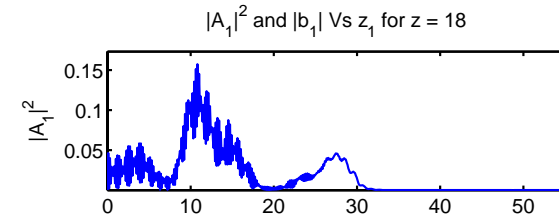
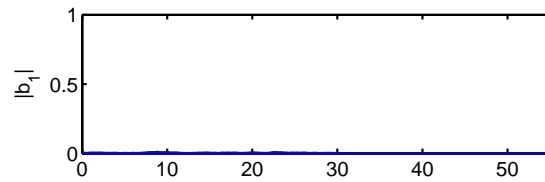
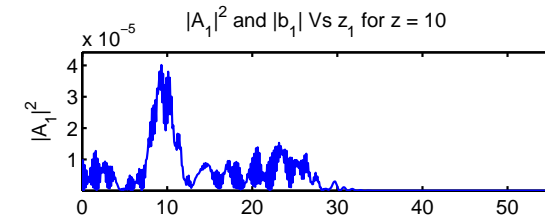
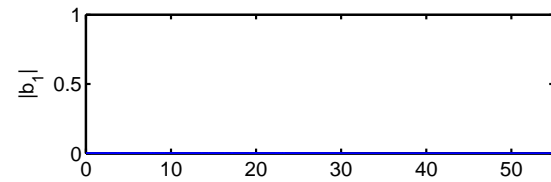
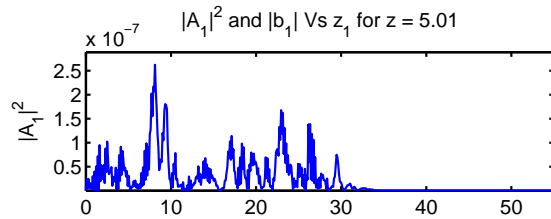
The integrated power gives the energy in the fundamental radiation pulse as a function of distance through the FEL.

The energy in the 3rd harmonic radiation pulse as a function of distance through the FEL.

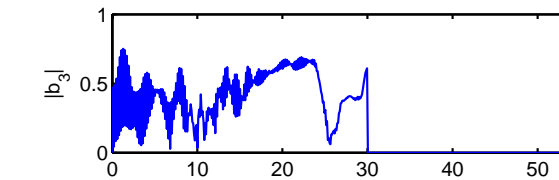
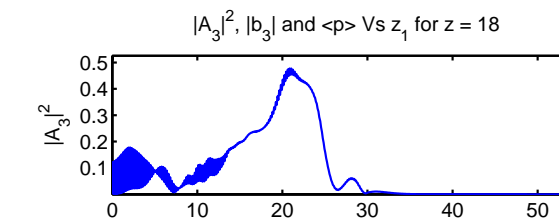
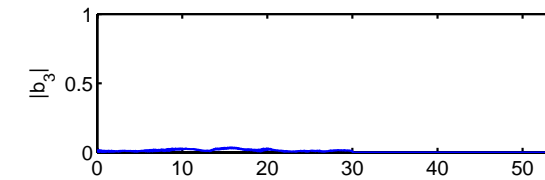
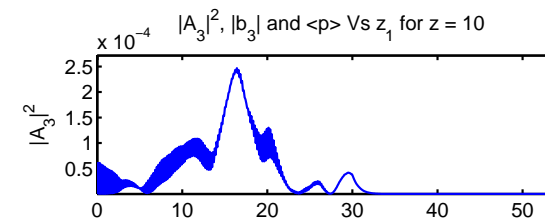
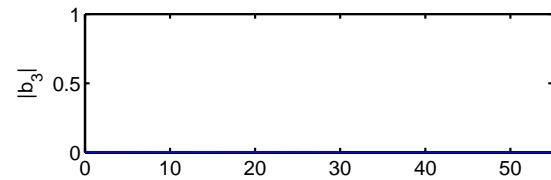
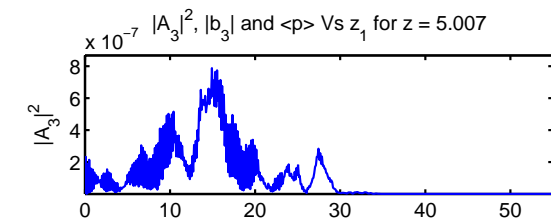


SASE Harmonic Amplifier FEL (pulses)

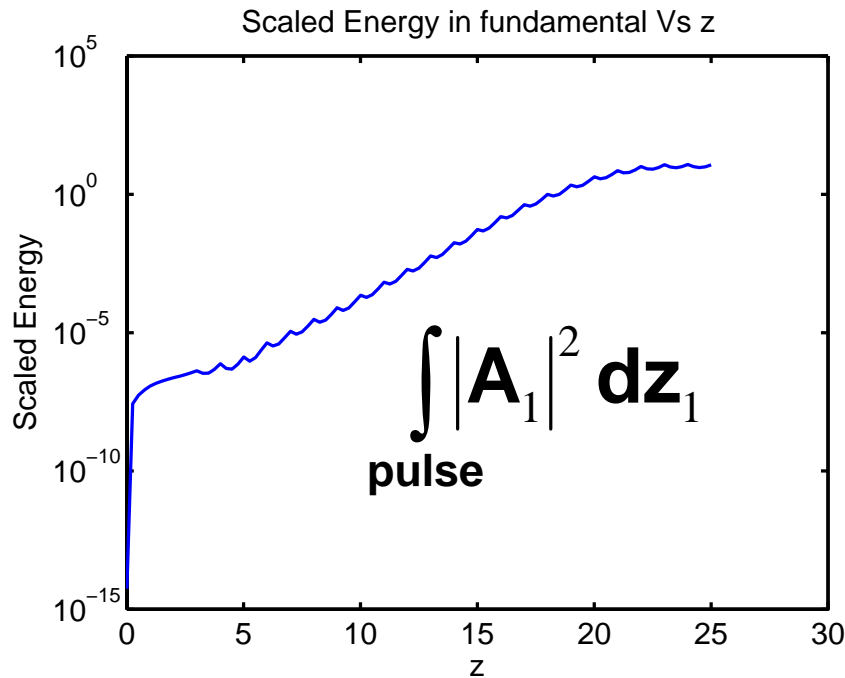
Fundamental:



3rd Harmonic:

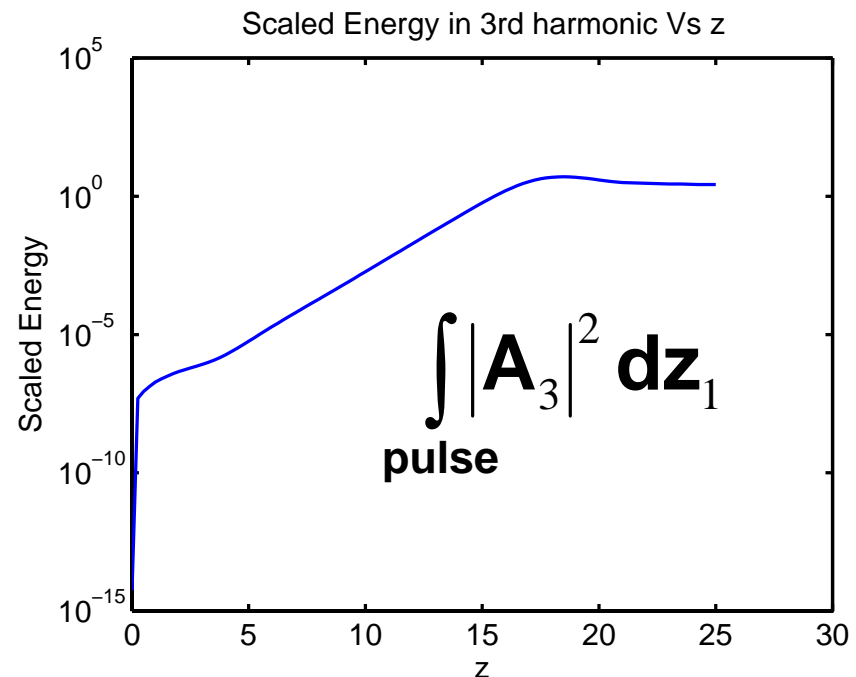



SASE Harmonic Amplifier FEL (pulses)



The integrated power gives the energy in the fundamental radiation pulse as a function of distance through the FEL.

The energy in the 3rd harmonic radiation pulse as a function of distance through the FEL.



Conclusions

- Density modulator with reduced dispersion
 - Can bunch particles using FEL-type instability but with reduced induced energy spread
 - Works for seeded amplifier, not from noise (SASE)
 - Could be used with emittance exchange methods* to improve beam emittance?
- Harmonic Amplifier FEL
 - Proof-of-principle modelling demonstrated FEL amplifier with dominant lasing at 3rd harmonic
 - Easy to implement in sectional undulator FELs

*M. Cornacchia and P. Emma, Phys. Rev. ST Accel. Beams, **5**, 084001, (2002)